FINAL REPORT

Big Dalton Perchlorate Removal Pilot Study

by

Calgon Carbon Corporation
Pittsburgh, PA

Submitted to

The Main San Gabriel Basin Water Master

October 30, 1998

EXECUTIVE SUMMARY

A study funded by the Main San Gabriel Watermaster to pilot **ISEP®** system for the removal of perchlorate from the Big Dalton site well water has been completed by Calgon Carbon Corporation. The pilot study, conducted between July 2-August 7, 1998, successfully demonstrated Calgon's continuous counter-current ion-exchange (**ISEP®**) system for the removal of perchlorate contamination from ground water. The process involves removal of anionic contaminants (perchlorate, nitrate and sulfate) in the feed water using an ion-exchange resin, which is continuously regenerated using relatively small amounts of brine. Non-detectable (< 4 ppb) levels of perchlorate in treated water were obtained from the system on a continuous basis. Concomitantly, the system was successful in removing more than 60% of influent nitrate contamination and more than 95% of influent sulfate. The pilot study was also successful in optimizing the operation of the system to produce minimal waste while achieving treatment objectives. At the end of the optimization study, it was apparent that non-detectable levels of perchlorate and substantial removal of nitrate and sulfate in treated water can be obtained on a continuous basis while generating a brine waste as low as 0.75%, based on the volume of feed water. Sufficient operating data were obtained from the pilot study to design full-scale perchlorate removal systems. Details of the system performance results and analytical reports have been included.

Scale-up parameters were developed using which the capital and operating costs of full-scale treatment systems were estimated. The cost of an integrated **ISEP®/Rayox®** treatment system for both perchlorate and NDMA removal was estimated for a full-scale system treating 1,500 gpm of well water at the Big Dalton site. The selling price of the integrated **ISEP®/Rayox®** system is estimated to be $1,850,000. Annual (350 days) operating costs (not including waste disposal costs) for the integrated system are estimated to be $570,000.

1.0 INTRODUCTION

Perchlorate and other anionic contaminants in ground water are effectively removed by ion-exchange, a process where contaminant anions are exchanged and replaced by an innocuous anion, typically chloride. Ion-exchange is one of the most effective methods for most ground water treatment applications due to its efficiency in removing contaminants present in varying concentrations at relatively low costs. Most of the ion-exchange resins manufactured are used for water treatment and ion-exchange resins have been treating drinking water for several years. Although ion-exchange technology is well-known, the effectiveness of an ion-exchange process depends, among other factors, on the operational configuration of the process. Key parameters that determine the efficiency and impact the economics of an ion-exchange process are treatment ratio and regeneration waste. Treatment ratio refers to the volume of feed water that can be treated before breakthrough of the contaminant(s) is obtained. Regeneration waste refers to the volume of waste generated by the ion-exchange process while regenerating the ion-exchange resin saturated with contaminants. An effective ion-exchange process is one that achieves high treatment ratios while producing low regeneration waste. Calgon Carbon's **ISEP®** system utilizes an effective ion-exchange process configuration that achieves high perchlorate treatment ratios while producing minimal waste.

Calgon Carbon utilized its patented multi-port **ISEP®** valve in developing an ion-exchange system for the removal of perchlorate and other anionic contaminants from ground water. This system bears some similarity to Calgon Carbon's **ISEP®**-based system used commercially for the treatment of nitrate from drinking water. The two fundamental advantages of the **ISEP®** system are better utilization of the mass transfer zone and continuous counter-current regeneration, both of which lead to high treatment ratios and low regeneration waste as compared to conventional ion-exchange processes using fixed bed systems. The **ISEP®** system involves sequential segmentation of the mass transfer zone leading to better utilization of the ion-exchange resin during the adsorption cycle.

In the regeneration cycle, the technology utilizes a staged counter-current mass transfer approach resulting in a highly effective utilization of the regenerant. The ability to vary the configuration of adsorption and regeneration zones independently to operate at their optimum efficiencies makes the **ISEP®**-based design effective, versatile and economical for ground water treatment applications involving ion-exchange.

2.0 PERCHLORATE REMOVAL PILOT TEST PROGRAM

Calgon Carbon was retained by the Main San Gabriel Basin Watermaster to demonstrate its **ISEP®** system for the removal of perchlorate contamination from the ground water at Big Dalton well site. Prior to undertaking the work, preliminary laboratory screening was conducted by Calgon Carbon to identify potential anion-exchange resins that would be effective for perchlorate removal in the **ISEP®** system. After screening several candidate resins, a suitable anion-exchange resin was chosen. This anion-exchange resin, when utilized in an **ISEP®**-based configuration, offered the optimal balance between contaminant selectivity, capacity and ease of regeneration. After the contractual agreement was signed, an **ISEP®** pilot system was built using the previously selected ion-exchange resin and the technology was continuously demonstrated at the Big Dalton site from July 3-August 7, 1998.

2.1 Pilot Program Objectives

The original objectives for the pilot program were revised by mutual agreement between Calgon Carbon and San Gabriel water master. Revisions to the original objectives were necessitated by delays caused in having the Big Dalton site ready for initiating Calgon Carbon's pilot study.

The **ISEP®** system, as implemented at Big Dalton site, does not feature the Brine Recycling Module, developed by Calgon Carbon to further minimize the waste from the process. The Brine Recycling Module could not be piloted at the Big Dalton site because the delays caused in site preparation led to contraction of the original pilot program. Therefore, the objectives relating to brine waste treatment in the original contract were not addressed. The revised objectives for the pilot program were to:

i) Demonstrate the feasibility of the **ISEP®** system to remove perchlorate in the influent water to less than 18 ppb.

ii) Verify ability to successfully regenerate the perchlorate-loaded resin.

iii) Verify and optimize system configuration and regenerate usage.

iv) Minimize the volume of waste from the system.

2.2 Technology Discussion

The conceptual diagram of the **ISEP®** system as implemented at Big Dalton is shown in Figure 1. In the process, the well water is passed through an a granular activated carbon (GAC) system that serves to remove any organic contaminants in the water. The organic-free well water is passed through the **ISEP®** system as indicated. The **ISEP®** system contains thirty (30) columns attached to the rotating portion of the multi-port valve. Each of the columns is packed with the chloride form of the chosen anion-exchange resin. The **ISEP®** columns can be divided into three functional zones, viz., adsorption, regeneration and rinse. The perchlorate (as well as nitrate and sulfate) present in the feed water is exchanged with chloride on the resin in the adsorption zone. The water thus treated by the columns in the adsorption zone can have non-detectable levels (< 4 ppb) of perchlorate. The resin containing adsorbed perchlorate.is treated in the regeneration zone using a brine solution that exchanges the perchlorate ions on the resin with the chloride ions from brine. The regenerant used for the Big Dalton study is a 7% brine solution prepared using softened city water. The brine flow direction in the regeneration zone is counter-current to direction of rotation of the columns, due to which sufficient concentration gradients between the brine phase and the resin phase are maintained in each column in the regeneration zone. The spent brine effluent from the regeneration zone understandably contains the perchlorate anions in a significantly higher concentration than the feed. The rinse zone serves to remove the entrained brine from the columns coming out of the regeneration zone before they enter the adsorption zone for the next cycle. The rinse flow effluent is a weak brine solution that is treated by the RO unit to produce a product and concentrate stream. The product stream is pure water which is used to make-up part of the rinse flow influent. The concentrate stream is a brine solution that is utilized to make-up fresh regenerant used in the regeneration zone.

The columns cycle through adsorption, regeneration and rinse zones with controllable residence times in each zone. The residence time calculations for each zone is translated into step time, which indicates the time for which the columns (and the valve) stay in one position. The step time for the **ISEP®** system during the Big Dalton pilot was set at 33.3 min. In other words, the 30-column **ISEP®** system took 16.7 hours to complete one rotation.

2.3 Sampling and Analysis Protocol

Samples of the various process streams in the **ISEP®** system were taken and characterized to monitor the performance of the system. The samples of various streams were collected at a slow rate over a period of one step to ensure minimal or no interference with the process. Samples were collected in 100 ml. plastic bottles and stored cold. The samples were shipped daily by overnight delivery to Calgon Carbon's central analytical facility in Pittsburgh where they were promptly analyzed. The sampling frequency varied for different streams based on process monitoring and optimization needs.

Analysis of the collected samples were conducted using two ion chromatography systems, one customized to detect low-level perchlorate and the second for other anions. The analytical method used for perchlorate and other anions was the EPA method 300.0 (modified) for anions analysis. The samples containing high brine concentrations were pre-treated by a silver nitrate cartridge to minimize the interference of chloride on perchlorate analysis.

2.4 Chronological Summary

A summary highlighting the sequence of events relating to the **ISEP®** system pilot at the Big Dalton site is shown in Table 1. These events, beginning June 27 till August 17, represent all of Calgon Carbon's activities at the pilot site.

Table 1. Chronological Summary of Pilot Testing Activities at the Big Dalton site.

Dates	*Events*
June 27-28	* Installed 10 GPM submersible pump * Installed mini-GAC system * Operated pump to fill 20,000 gal. storage tank
June 28-July 1	* Mini-GAC system on-line and confirmation of perchlorate breakthrough
July 2	* **ISEP®** start-up checks completed
July 3	* **ISEP®** system operation started * System performance validated
July 3-July 23	* Steady-state operation of system confirmed * Process optimization program conducted * Periodic sample collection and analyses conducted
July 24	* Feed spiking system to spike influent perchlorate to 50-70 ppb on-line
July 24-August 6	* Process optimization program completed * Periodic sample collection and analyses conducted
August 7	* **ISEP®** system shutdown
August 7-14	* **ISEP®** system dismantled and transported from site * Submersible pump removed from Big Dalton well
August 14	* **ISEP®** regenerate waste (brine) disposed by Laidlaw Environmental Services
August 17	* Regenerate waste storage tank removed from site * Site restoration completed

2.5 Results and Discussion

The **ISEP®** pilot system at Big Dalton site was designed to treat 4.28 GPM (16200 ml/min.) of well water continuously. Over the period of pilot operation, the volume of water treated was well in excess of 200,000 gallons. Analytical results showing perchlorate, nitrate, sulfate and chloride concentrations of influent (S1) water, treated (S2) water and other streams from the pilot are listed in Appendix A. Some of these data are presented in Figures 2-4.

Start-up and Design Validation

The start-up regeneration flow rate was set at 324 ml/min that results in a brine waste flow rate of 310 ml/min. This corresponds to a 2% waste stream, based on the volume of influent water. The rinse flow was set at 81 ml/min., which corresponds to 0.5% of the influent flow. The start-up regeneration and rinse flow rates were calculated based on laboratory column studies and Calgon Carbon's prior experience in designing **ISEP®**-based systems. The data indicated that the system reached steady state within three rotations (2 days) of start-up. The results indicated that at the start-up design conditions, non-detectable levels of perchlorate were observed in treated water at steady state.

Process Optimization and Waste Reduction

The perchlorate removal performance of the **ISEP®** system as a function of on-stream time is shown in Figure 2. The time axis is represented as days of operation starting July 3. As shown, the steady state performance of **ISEP®** in removing perchlorate in influent water to non-detectable levels was demonstrated continuously for the first several days before the process optimization program was initiated. After every process change, the **ISEP®** system was allowed to reach steady state at the new conditions. The percentage numbers indicated in Figure 2 at different points on the abscissa refer to the percentage waste from the process. For example, the 1.0% on Day 14 indicates that the **ISEP®** system was optimized to produce a regenerate (brine) waste of 1.0% (as compared to the original design of 2% waste) on Day 14 of operation.

As is evident in Figure 2, the waste from the process was sequentially decreased while the system was continuously producing treated water with non-detectable levels of perchlorate. An objective of the optimization program was to minimize the waste from the process while maintaining satisfactory perchlorate treatment performance. Towards that end, the process was deliberately set to a level where perchlorate breakthrough was expected to occur. When the process waste was reduced to 0.5%, perchlorate was detected in the treated water. However, the detected perchlorate concentrations were still well below the California provisional action level (PAL) of 18 ppb. Around the same time, the perchlorate concentration in the feed water to our process had declined substantially (~20 ppb). Analytical results indicated that the other anions (sulfate, chloride and nitrate) in the feed water also changed continuously throughout the study, but the variations were not as substantial as perchlorate. In order to conduct meaningful optimization of the **ISEP®** system, the perchlorate concentration in the feed was spiked to 50-75 ppb level using a concentrated stock solution. Thorough mixing of the stock solution with the feed water was ensured by using an in-line static mixer and maintaining turbulent flow inside the feed line. The spiking of feed also served to examine the response of the **ISEP®** system to sudden influent variation. As shown by the results in Figure 2, the system handled the spike satisfactorily and continued to produce treated water below California PAL. In order to demonstrate that the system is controllable, the system parameters were modified to produce a brine waste of 0.75%, and the treated water showed non-detectable perchlorate concentration. At this point, our regenerant optimization program as intended in our objectives, was completed. However, to better understand the regeneration dynamics, an additional process change was made in which the concentration of the regenerant was increased from 7% brine to 11% brine and the waste was reduced to 0.5%. The pilot test was concluded at these conditions. These regeneration conditions produced a treated water with perchlorate concentrations in 7-9 ppb range, well below the California PAL of 18 ppb.

In addition to perchlorate, we continuously monitored the concentration of nitrate, sulfate and chloride ions in various streams. The influent and treated water nitrate concentrations observed during this pilot test are shown in Figure 3. It is evident that while the influent water nitrate concentration was in 20-28 ppm range, the treated water had nitrate concentration primarily in the 5-10 ppm range. The process consistently reduced the influent nitrate levels by over 60%. This is a significant additional advantage of the **ISEP®** system, which is optimized for perchlorate removal. In addition, the process also removed substantial amounts of sulfate present in the feed water as shown in Figure 4. Influent feed sulfate concentrations in 41-67 ppm range were reduced to 0-2 ppm in treated water at the perchlorate treatment conditions, corresponding to a removal efficiency of 95-99.9%.

Another aspect of the **ISEP®** system optimization program relates to the rinse zone. It was mentioned that the start-up rinse flow was set at 81 ml/min, or about 0.5% of the feed water. The objective of the rinse zone is to remove the regenerant (brine) present in the columns before they re-enter the adsorption zone. Towards the end of the regenerant optimization program, the rinse flow was reduced and its impact on rinse efficiency was monitored. By reducing the rinse flow to a level where brine entrainment was observed, the rinse flow was minimized to 30 ml/min. At this flow, it was confirmed that the rinse was both effective and efficient in removing entrained brine from the columns.

Independent Validation of Analytical Results

In addition to periodic sample collection and analyses by Calgon Carbon, the Main San Gabriel Water Master arranged for independent sampling and analyses of the **ISEP®** system streams. The independent sampling and analyses were conducted by McGuire Environmental Consultants, Inc. A memorandum from McGuire Environmental Consultants summarizing their analysis and results obtained from the Big Dalton Perchlorate Removal Pilot Study is attached in Appendix B. The sampled streams were analyzed for perchlorate, nitrate, sulfate, chloride, TOC, TDS, conductivity, pH and alkalinity. Comparison of these results obtained for the influent and treated water samples with those obtained by Calgon Carbon (Appendix A) indicate that they are in very good agreement with each other. Differences in results obtained in the analyses of initial samples of brine waste (S15) between Appendix B and Appendix A are attributable to the sampling protocol. The first four brine waste samples collected by McGuire Environmental Consultants were spot (`grab') samples as opposed to Calgon Carbon who collected each brine waste sample over a period of one step time (33.3 min.). The concentration profiles in **ISEP®** regeneration zone vary within a step and are repeated for each step. Taking an averaged sample over one step serves to determine true trends in brine waste concentrations over multiple rotations, thereby eliminating the influence of concentration variation within a step. After McGuire Environmental Consultants began taking time-averaged samples, it is evident that there is better agreement between their results and those of Calgon Carbon. In summary, McGuire Environmental Consultants' analytical results are consistent with those of Calgon Carbon. Calgon Carbon sincerely acknowledges McGuire Environmental Consultants for providing their analytical results for inclusion in this report.

Interpretation of Process Performance

The pilot results demonstrate that Calgon Carbon's **ISEP®** system is effective in removing perchlorate in influent water to a non-detectable level. In addition, the system reduces nitrate and sulfate present in influent water to substantially low levels.

Reducing the regenerate waste involves reducing the brine flow to the regeneration zone. This reduces the equivalent amounts of chloride available to replace the perchlorate, nitrate and sulfate saturated on the resin. In other words, achieving sustainable treatment performance while generating low waste volumes implies high efficiency of regeneration in **ISEP®** system. This is due to better utilization of brine achieved in a counter-current staged ion-exchange configuration. The brine waste obtained from the **ISEP®** system is therefore high in contaminant concentrations. The typical concentration ranges observed in the influent water, treated water and regenerant waste are shown in Table 2.

Table 2. Typical Flows and Compositions of Influent, Treated and Waste Streams from Pilot Study.

	Influent	*Treated*	*Waste*
Flow rate	4.28 GPM	~4.28 GPM	~0.032 GPM (0.75%)
Compositions			
Perchlorate	18-76 ppb	**< 4 ppb**	2-10 ppm
Nitrate	20-28 ppm	**5-14 ppm**	800-1,900 ppm
Sulfate	41-67 ppm	0.1-2 ppm	3,000-9,000 ppm
Chloride	20-35 ppm	70-120 ppm	~25,000-40,000 ppm (~7 wt% NaCl)

It is important to note that the compositions of treated water and waste shown in Table 2 are for a specific waste level and **ISEP®** configuration as operated at Big Dalton site. Clearly, if the influent process conditions and process parameters are changed, the compositions are likely to change. However, the **ISEP®** system can be configured to achieve or even exceed given treatment objectives. As operated at Big Dalton, it is possible to achieve a waste volume in 0.5-0.75% range while maintaining non-detectable levels of perchlorate in treated water.

By reducing the rinse flow by a factor of 2.7 (from 81 ml/min to 30 ml/min), the size of the RO system at the commercial level is reduced by a corresponding level thereby reducing capital costs. At the same time, a lower rinse flow (less than 30 ml/min) leads to inefficient rinse resulting in entrained brine carrying over to the adsorption zone. This results in a slight elevation in chloride concentration of the treated water. This may be an acceptable scenario in certain situations. It is important to recognize there is more than one feasible configuration of the **ISEP®** system for perchlorate removal. Discussion of each of the feasible **ISEP®** system configurations is beyond the scope of this report. The choice of a particular **ISEP®** system configuration will depend, among other factors, on feed compositions, treatment objectives, allowable concentrations of anions, waste volume concerns and their impact on capital and operating costs.

3.0 SCALE-UP AND ECONOMICS

Calgon Carbon has developed validated guidelines for scaling **ISEP®** pilot performance data into full-scale systems. Calgon Carbon's extensive experience in designing and operating full-scale water treatment systems, most notably, the **ISEP®**-based nitrate removal systems, has enabled the reliable scale-up of perchlorate removal pilot performance at Big Dalton site. Calgon Carbon is currently developing a brine recycling module to further minimize the waste from the **ISEP®** system. The **ISEP®** system as implemented at Big Dalton site can be implemented in full-scale either with or without the brine recycling module.

Calgon Carbon estimated the capital and operating costs of a full-scale integrated system for perchlorate and N-nitrosodimethylamine (NDMA) removal for the conditions at the Big Dalton site. Since NDMA is present in addition to perchlorate in Big Dalton site, Calgon Carbon proposed an integrated system in which the **ISEP®** system removes perchlorate and a UV-based system (**Rayox®**) removes NDMA. As per request by Stetson Engineers, a preliminary cost estimate (dated September 4, 1998) for an integrated full-scale system treating 1,500 gpm of water at Big Dalton site was submitted. This cost estimate was prepared based on the **ISEP®** system pilot performance results from Big Dalton site. With the analyzed conditions at Big Dalton site, a full-scale **ISEP®/Rayox®** integrated system treating 1,500 gpm of feed water to produce a treated water with non-detectable levels of both perchlorate (<4 ppb) and NDMA (< 0.002 ppb), in addition to substantially reduced nitrate and sulfate levels, is estimated to have a selling price of $1,850,000. Other costs related to installation and building are highly site-dependent and would therefore influence the total installed costs. As a rough estimate, installation costs may range from $200,000-400,000 and building costs may be near $90,000 (1800 ft^2 at $50/$ft^2$). Annual (350 days) operating cost of the treatment system is estimated as $570,000. The annual operating costs do not include the waste disposal costs. For further details, please contact Calgon Carbon Corporation.

4.0 CONCLUSIONS

Calgon Carbon has successfully demonstrated its **ISEP®** system for the removal of perchlorate from feed water at San Gabriel Valley's Big Dalton site. All of the revised pilot objectives, set forth prior to the start of the pilot, were accomplished in this pilot study. The results from the pilot indicate that non-detectable levels of perchlorate in treated water can be achieved on a continuous basis while producing a low waste stream of 0.75%, based on the volume of influent water. The results also indicate that in addition to perchlorate removal, substantial amounts of influent nitrate and sulfate are also removed. Successful operation over a period of about five weeks has enabled Calgon Carbon to obtain sufficient operating data and optimize the **ISEP®** system. The system is now available for commercial applications. Using validated scale-up factors, capital and operating costs of full-scale **ISEP®** systems for perchlorate removal were developed.

5.0 RECOMMENDATIONS

Based on the results obtained from the Big Dalton pilot study and internal performance validation of **ISEP®** system, Calgon Carbon recommends that the **ISEP®** system be implemented at San Gabriel Valley's sites contaminated with perchlorate. The **ISEP®** system may be implemented with either brine waste disposal (as piloted at Big Dalton site) or with a brine recycling module to destroy the perchlorate and nitrate present in the brine waste and to further minimize the waste stream.

LIST OF APPENDICES

APPENDIX A: Results of *perchlorate, nitrate*, *sulfate* and *chloride* analyses of the samples generated from the **ISEP®** system during the Big Dalton Perchlorate Pilot Study.

APPENDIX B: Memorandum from *McGuire Environmental Consultants* dated Sept. 17, 1998) summarizing the results obtained from their independent analyses of **ISEP®** system samples.

Figure 1. Conceptual Diagram of Calgon Carbon's ISEP+ process as implemented at Big Dalton site.

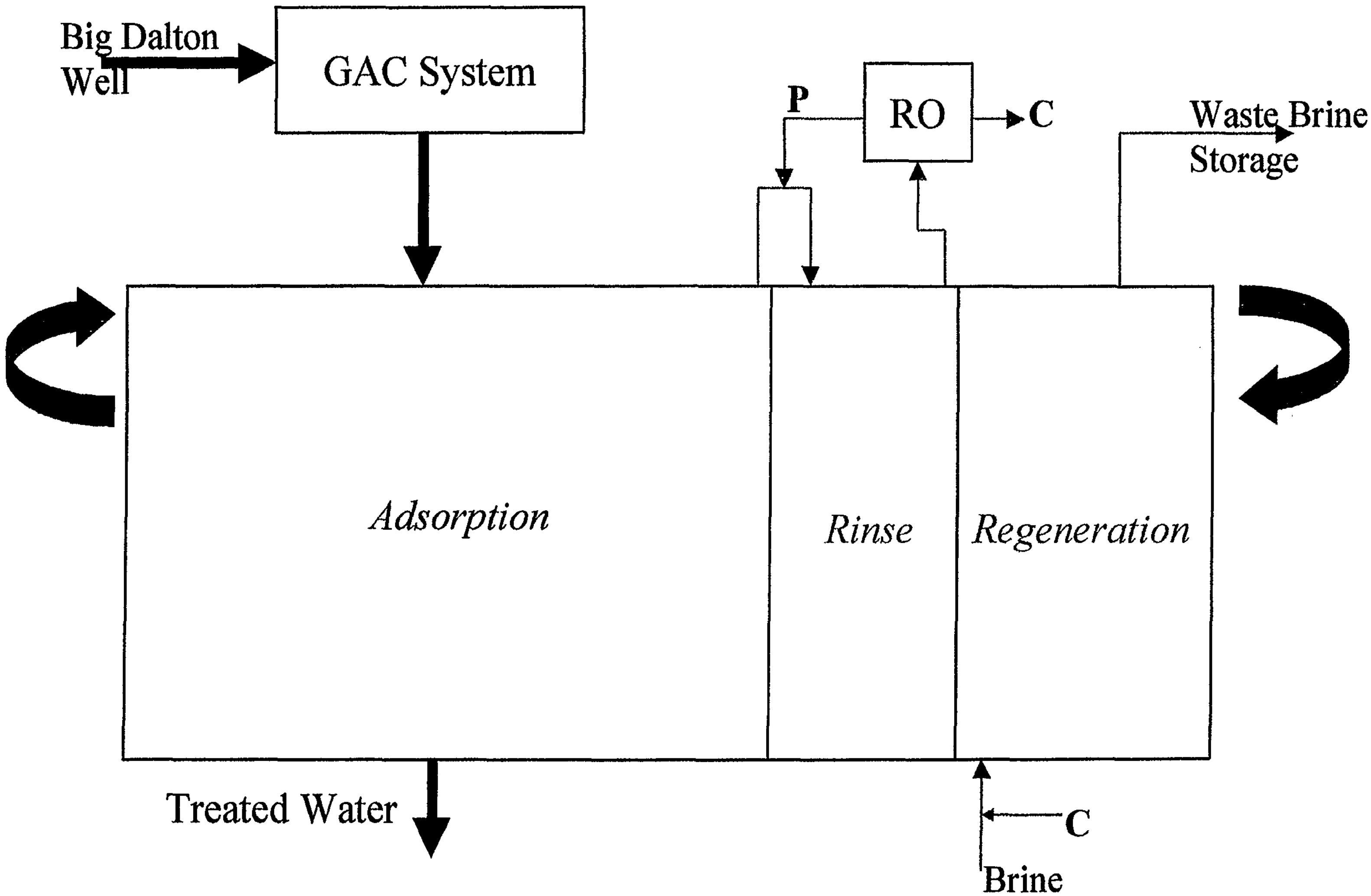


Figure 2. Perchlorate Concentrations of Feed and Treated Water from ISEP+ Pilot Study at Big Dalton site (Values at 0 ppb denote non-detectable [less than 4 ppb] values)

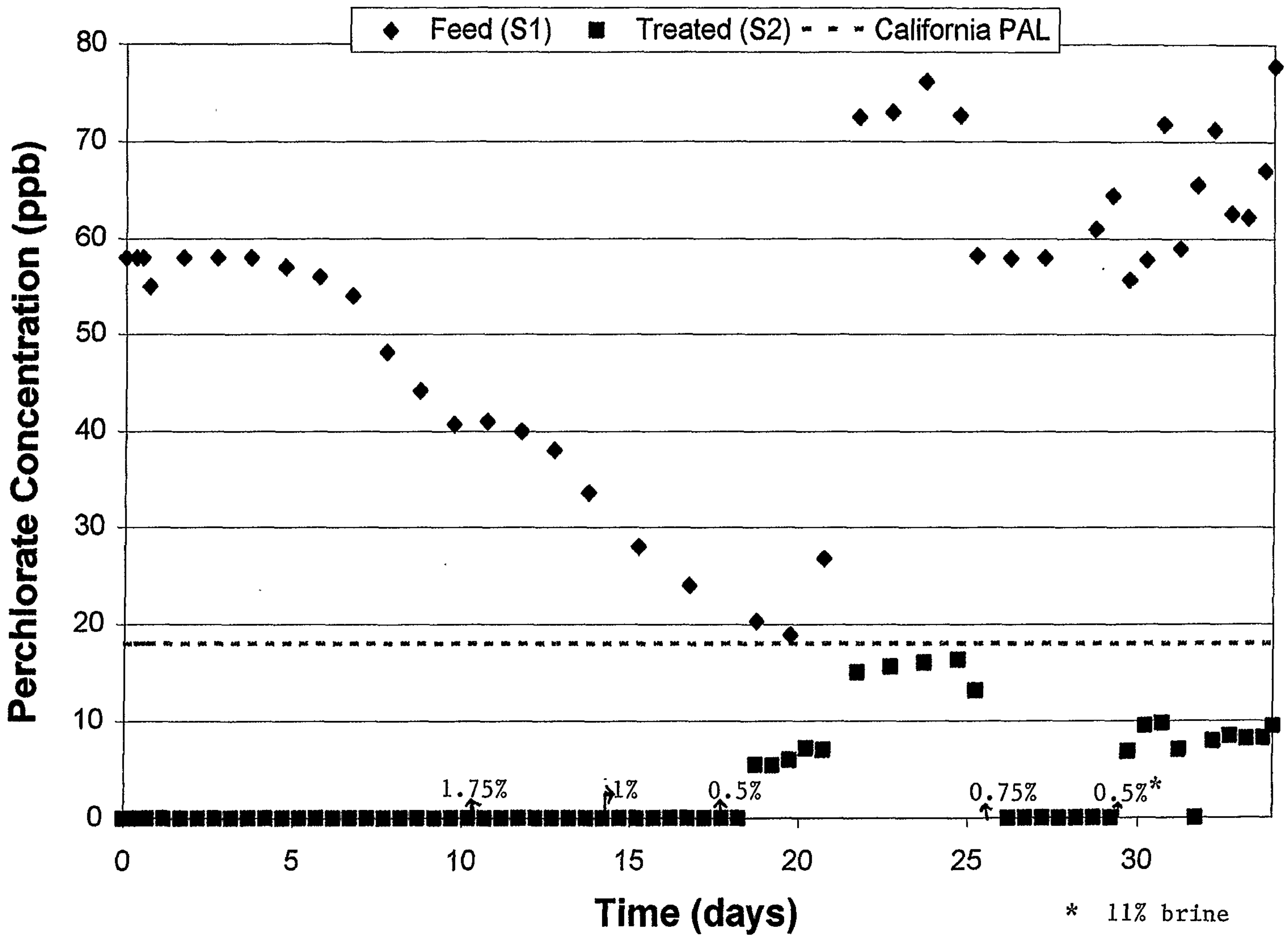


Figure 3. Nitrate Concentrations of Feed and Treated Water from ISEP+ Pilot Study at Big Dalton site.

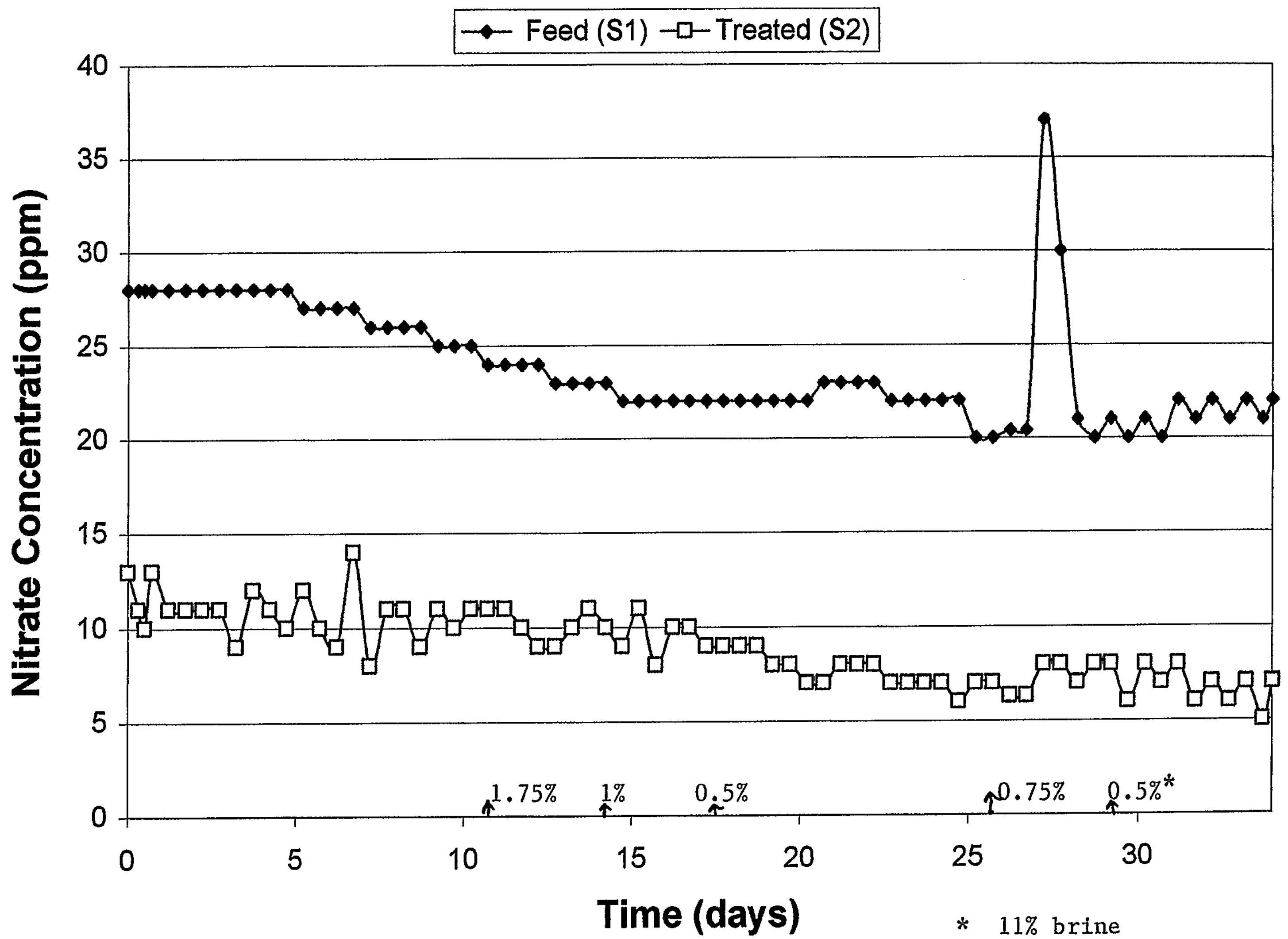
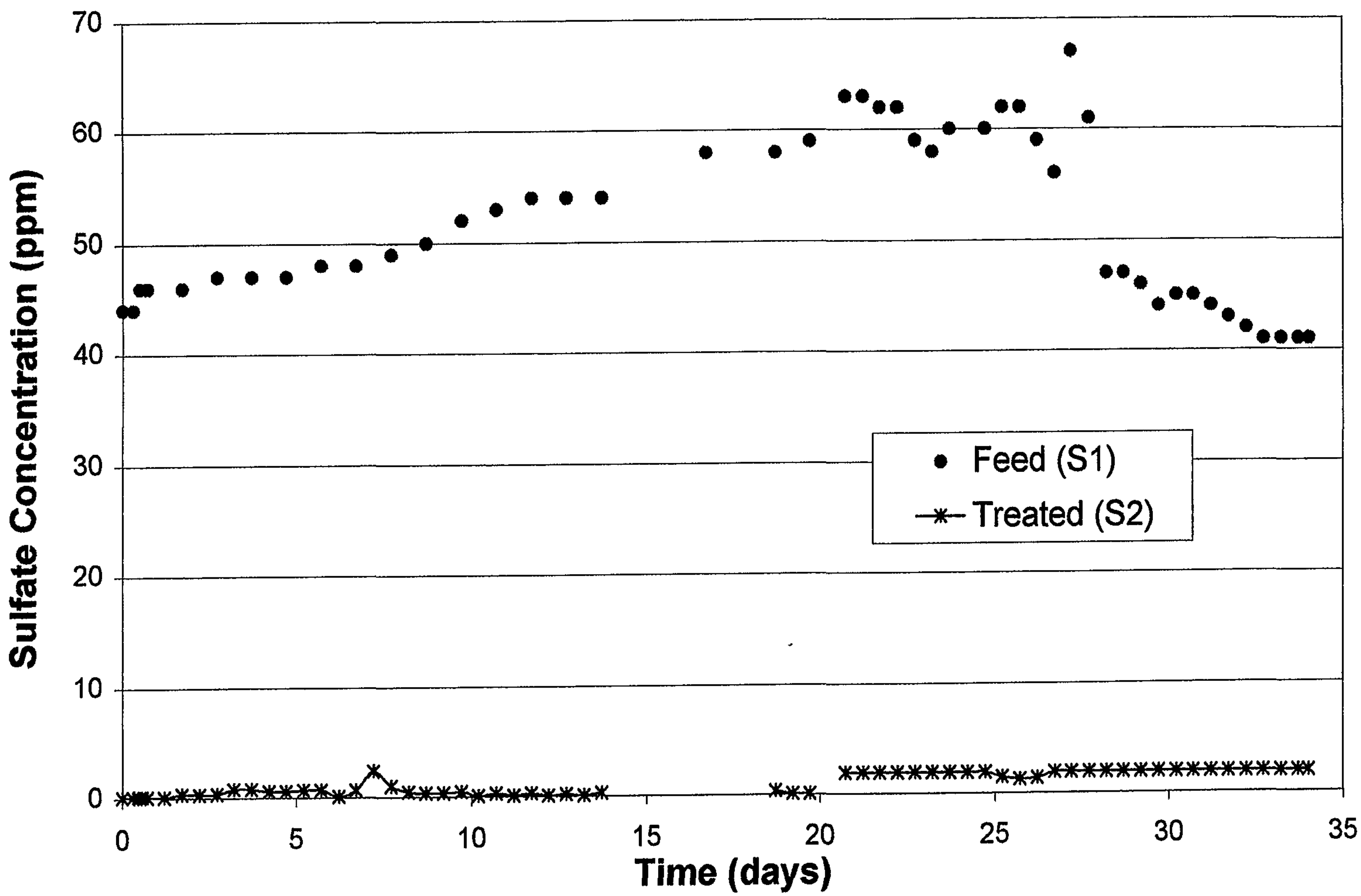


Figure 4. Sulfate Concentrations of Feed and Treated Water from ISEP+ Pilot Study at Big Dalton site. (Values at 0 and 1.9 ppm denote <0.2 and <2 ppm, respectively)



Appendix A

Data Table for Perchlorate Removal at Big Dalton Well in San Gabriel CA

Date/Time well was started with auxilliary pump by CCC/AES. 6/27/98 08:00
Date/Time granular activated carbon was started by CCC/AES. 06/28/98 8:00
Date/Time perchlorate removal was started by CCC/AES. 07/03/98 15:30

	(Hours)		UNTREATED WELL WATER							GAC TREATED WELL WATER						
	GAC	System	(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(μOhm/cm)		(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(μOhm/cm)	
Date/Time	Run Time	Run Time	ClO4	NO3	SO4	Cl	F	Cond.	pH	ClO4	NO3	SO4	Cl	F	Cond.	pH
6/27/98 10:00			62	29	45	18	0.3	525	7.78							
6/28/98 10:00	2		65	29	44	17	0.2	510	7.8	2.5	3	37	17	0.2	455	7.97
6/29/98 8:00	24		64	29	44	17	0.2	530	7.88	10	28	44	18	0.2	500	8.6
6/30/98 9:30	49.5		64	28	45	13	0.2	515	7.74	24	28	45	19	0.2	515	7.92
7/1/98 8:00	72		62	28	44	13	0.2			37	28	45	13	0.2		
7/2/98 8:00	96		64	28	44	18	0.2			47	28	44	13	0.2		
7/3/98 10:00	120	0								64	28	44	17			
7/3/98 22:30	132.5	7.5														
7/4/98 4:00	138	12.5														
7/4/98 8:00	142	16.5								55	28	44	17			
7/4/98 16:00	150	24.5														
7/5/98 0:00	158	32.5														
7/5/98 8:00	166	40.5														
7/5/98 16:00	174	48.5														
7/6/98 0:00	182	56.5														
7/6/98 8:00	190	64.5								58						
7/6/98 16:00	198	72.5														
7/7/98 0:00	206	80.5														
7/7/98 8:00	214	88.5								58	28	47	19			
7/7/98 15:00	221	95.5														
7/7/98 20:00	226	100.5														
7/8/98 8:00	238	112.5								57	22	48	27			
7/8/98 20:00	250	124.5														
7/9/98 20:00	274	148.5														
7/10/98 8:00	286	160.5														
7/10/98 20:00	298	172.5														
7/11/98 8:00	310	184.5														
7/11/98 20:00	322	196.5														
7/12/98 8:00	334	208.5														
7/12/98 20:00	346	220.5														
7/13/98 8:00	358	232.5														
7/13/98 20:00	370	244.5								41						
7/14/98 8:00	382	256.5								41						
7/14/98 20:00	394	268.5														
7/15/98 8:00	406	280.5								40						

		Feed Results							
	(Hours)		UNTREATED WELL WATER						
	GAC	System	(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(µOhm/cm)	
Date/Time	Run Time	Run Time	ClO4	NO3	SO4	Cl	F	Cond.	pH
7/18/98 8:00	478	352.5							
7/18/98 20:00	490	364.5							
7/19/98 8:00	502	376.5							
7/19/98 20:00	514	388.5							
7/20/98 8:00	526	400.5							
7/20/98 20:00	538	412.5	Begin Spike Feed						
7/21/98 8:00	550	424.5	15	22	60	29			
7/21/98 20:00	562	436.5							
7/22/98 8:00	574	448.5	16	23	61	30			
7/22/98 20:00	586	460.5	17						
7/23/98 8:00	598	472.5	15	22	62	30			
7/23/98 20:00	610	484.6	19						
7/24/98 8:00	622	496.5	17	22	30	62			
7/24/98 20:00	634	508.5	16						
7/25/98 8:00	646	520.5	14						
7/25/98 20:00	658	532.5	20	22	34	59			
7/26/98 8:00	670	544.5	15	21	36	62			
7/26/98 20:00	682	556.5	18	21	34	58			
7/27/98 8:00	694	568.5	20	22	31	57			
7/27/98 14:00	701	580.5							
7/28/98 8:00	718	592.5	31	22	56	32			
7/28/98 20:00	730	604.5							
7/29/98 8:00	742	616.5	25	20	47	32			
7/29/98 20:00	754	628.5	24	20	46	30			
7/30/98 8:00	766	640.5	26	20	47	31			
7/30/98 20:00	778	652.5	29	24	56	35			
7/31/98 8:00	790	664.5	29	26	67	36			
7/31/98 20:00	802	686.5	29						
8/1/98 8:00	814	698.5	26						
8/1/98 20:00	826	710.5	30						
8/2/98 8:00	838	722.5	27						
8/2/98 20:00	850	734.5	31						
8/3/98 8:00	862	746.5	32						
8/3/98 20:00	874	758.5	33	21	42	30			
8/4/98 8:00	886	770.5	31						
8/4/98 20:00	898	782.5	36	22	42	30			
8/5/98 8:00	910	794.5	34	33	72	31			
8/5/98 20:00	922	806.5	38	21	41	23			
8/6/98 8:00	934	818.5	33	21	41	28			
8/6/98 16:00	946	830.5	38	22	42	24			

	(Hours)		GAC TREATED WELL WATER						
	GAC	System	(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(µOhm/cm)	
Date/Time	Run Time	Run Time	ClO4	NO3	SO4	Cl	F	Cond.	pH
6/27/98 10:00									
6/28/98 10:00	2		2.5	3	37	17	0.2	455	7.97
6/29/98 8:00	24		10	28	44	18	0.2	500	8.6
6/30/98 9:30	49.5		24	28	45	19	0.2	515	7.92
7/1/98 8:00	72		37	28	45	13	0.2		
7/2/98 8:00	96		47	28	44	13	0.2		
7/3/98 10:00	120	0	64	28	44	17			
7/3/98 22:30	132.5	7.5							
7/4/98 4:00	138	12.5							
7/4/98 8:00	142	16.5	55	28	44	17			
7/4/98 16:00	150	24.5							
7/5/98 0:00	158	32.5							
7/5/98 8:00	166	40.5							
7/5/98 16:00	174	48.5							
7/6/98 0:00	182	56.5							
7/6/98 8:00	190	64.5	68						
7/6/98 16:00	198	72.5							
7/7/98 0:00	206	80.5							
7/7/98 8:00	214	88.5	58	28	47	19			
7/7/98 15:00	221	95.5							
7/7/98 20:00	226	100.5							
7/8/98 8:00	238	112.5	57	22	48	27			
7/8/98 20:00	250	124.5							
7/9/98 20:00	274	148.5							
7/10/98 8:00	286	160.5							
7/10/98 20:00	298	172.5							
7/11/98 8:00	310	184.5							
7/11/98 20:00	322	196.5							
7/12/98 8:00	334	208.5							
7/12/98 20:00	346	220.5							
7/13/98 8:00	358	232.5							
7/13/98 20:00	370	244.5	41						
7/14/98 8:00	382	256.5	41						
7/14/98 20:00	394	268.5							
7/15/98 8:00	406	280.5	40						
7/15/98 20:00	418	292.5							
7/16/98 8:00	430	304.5	38						
7/16/98 20:00	442	316.5							
7/17/98 8:00	454	328.5	34						
7/17/98 20:00	466	340.5							

	(Hours)		PERCHLORATE ANALYSIS RESULTS (PPB)												
	GAC	System	SAMPLE PORTS												
Date/Time	Run Time	Run Time	S2	S2-01	S2-06	S2-10	S2-14	S2-18	S4	S6	S9	S11	S13	S15	S17
07/18/98 08:00	478	352.5	<2.5							<2.5				2080	
07/18/98 20:00	490	364.5	<2.5							<2.5				2140	52
07/19/98 08:00	502	376.5	<2.5						<2.5	<2.5				1860	
07/19/98 20:00	514	388.5	<2.5							<2.5				1640	51
07/20/98 08:00	526	400.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5		<2.5				1510	
07/20/98 20:00	538	412.5	<2.5						<2.5	<2.5				1300	43
07/21/98 08:00	550	424.5	<2.5							<2.5				1340	
07/21/98 20:00	562	436.5	<2.5							<2.5				1500	20
07/22/98 08:00	574	448.5	5.5						<2.5	<2.5				1510	
07/22/98 20:00	586	460.5	5.4						<2.5	<2.5				1420	20
07/23/98 08:00	598	472.5	6						<2.5	<2.5				2110	
07/23/98 20:00	610	484.5	7.2						<2.5	<2.5				5880	140
07/24/98 08:00	622	496.5	7							<2.5				4310	
07/24/98 20:00	634	508.5	7.6							<2.5				5190	150
07/25/98 08:00	646	520.5	9						5.7	<2.5				5450	
07/25/98 20:00	658	532.5	12							<2.5				7610	76
07/26/98 08:00	670	544.5	12							<2.5					
07/26/98 20:00	682	556.5	12						6.4	<2.5					
07/27/98 08:00	694	568.5	16							<2.5				10800	
07/27/98 14:00	701	580.5		38	21	13	11	7.3						6370	100
07/28/98 08:00	718	592.5												7070	
07/28/98 20:00	730	604.5	13							<2.5				4840	126
07/29/98 08:00	742	616.5	<2.5							<2.5				6480	
07/29/98 20:00	754	628.5	<2.5						<2.5	<12				5900	121
07/30/98 08:00	766	640.5	<2.5							75				7310	
07/30/98 20:00	778	652.5	<2.5						<2.5	<12				7320	149
07/31/98 08:00	790	664.5	<2.5							<12				6350	
07/31/98 20:00	802	686.5	<2.5							<12				7630	71
08/01/98 08:00	814	698.5	<2.5							<12				8990	
08/01/98 20:00	826	710.5	<2.5							<12				8770	112
08/02/98 08:00	838	722.5	6.8							<12				9500	
08/02/98 20:00	850	734.5	9.5						<2.5	<12				10500	127
08/03/98 08:00	862	746.5	9.7							<12				9820	
08/03/98 20:00	874	758.5	7							<12				11900	69
08/04/98 08:00	886	770.5	<2.5						<2.5	<12				11600	
08/04/98 20:00	898	782.5	8							82				10400	67
08/05/98 08:00	910	794.5	8							<12				11500	
08/05/98 20:00	922	806.5	8						5.8	216					
08/06/98 08:00	934	818.5	8							259					
08/06/98 16:00	946	830.5	9							142					

		Perchlorate Results													
	(Hours)		PERCHLORATE ANALYSIS RESULTS (PPB)												
	GAC	System	SAMPLE PORTS												
Date/Time	Run Time	Run Time	S2	S2-01	S2-06	S2-10	S2-14	S2-18	S4	S6	S9	S11	S13	S15	S17
6/27/98 10:00															
6/28/98 10:00	2														
6/29/98 8:00	24														
6/30/98 9:30	49.5														
7/1/98 8:00	72														
7/2/98 8:00	96														
7/3/98 10:00	120	0													
7/3/98 22:30	132.5	7.5	<2.5	2.5	2.5		2.5	2.5							60
7/4/98 4:00	138	12.5	<2.5	2.5	2.5		2.5	2.5							106
7/4/98 8:00	142	16.5	<2.5												69
7/4/98 16:00	150	24.5	<2.5	2.5	2.5	2.5	2.5	2.5							90
7/5/98 0:00	158	32.5	<2.5												127
7/5/98 8:00	166	40.5	<2.5												100
7/5/98 16:00	174	48.5	<2.5	2.5	2.5	2.5	2.5	2.5		2.5					101
7/6/98 0:00	182	56.5	<2.5												
7/6/98 8:00	190	64.5	<2.5						2.5	2.5				4200	139
7/6/98 16:00	198	72.5	<2.5												83
7/7/98 0:00	206	80.5	<2.5												84
7/7/98 8:00	214	88.5	<2.5								2.5	2.5	2.5		96
7/7/98 15:00	221	95.5	<2.5								2.5	2.5	2.5		58
7/7/98 20:00	226	100.5	<2.5												
7/8/98 8:00	238	112.5	<2.5												
7/8/98 20:00	250	124.5	<2.5												
7/9/98 20:00	274	148.5	<2.5												
7/10/98 8:00	286	160.5	<2.5						2.5	2.5				2710	65
7/10/98 20:00	298	172.5												1470	
7/11/98 8:00	310	184.5												1900	
7/11/98 20:00	322	196.5												1530	
7/12/98 8:00	334	208.5												1350	
7/12/98 20:00	346	220.5													
7/13/98 8:00	358	232.5	<2.5						<2.5	<2.5				4110	79
7/13/98 20:00	370	244.5	<2.5							<4				2860	
7/14/98 8:00	382	256.5	<2.5							<50				1510	97
7/14/98 20:00	394	268.5	<2.5							<2.5				2520	
7/15/98 8:00	406	280.5	<2.5							<2.5				3860	
7/15/98 20:00	418	292.5	<2.5							<25				2500	
7/16/98 8:00	430	304.5	<2.5							<2.5					
7/16/98 20:00	442	316.5								<25				2400	
7/17/98 8:00	454	328.5	<2.5							<25				2860	
7/17/98 20:00	466	340.5	<2.5						<2.5	<2.5				2160	

	(Hours)		NITRATE ANALYSIS RESULTS (PPM)													
	GAC	System	SAMPLE PORTS													
Date/Time	Run Time	Run Time	S1	S2	S2-01	S2-06	S2-10	S2-14	S2-18	S4	S6	S9	S11	S13	S15	S17
7/18/98 8:00	478	352.5	22	9												
7/18/98 20:00	490	364.5		11												
7/19/98 8:00	502	376.5		8						<0.2						
7/19/98 20:00	514	388.5	22	10												
7/20/98 8:00	526	400.5	22	10												
7/20/98 20:00	538	412.5		9	32	21	2	<0.2	<0.2							
7/21/98 8:00	550	424.5	22	10												
7/21/98 20:00	562	436.5		10												
7/22/98 8:00	574	448.5	22	11						<2						
7/22/98 20:00	586	460.5		9						<2						
7/23/98 8:00	598	472.5	22	9						<2						
7/23/98 20:00	610	484.5		11						<2	<20				1600	
7/24/98 8:00	622	496.5	22	8							<20				1600	
7/24/98 20:00	634	508.5	23	7							<200				1540	
7/25/98 8:00	646	520.5	22	8						<2	<200				1560	43
7/25/98 20:00	658	532.5	22	8							<200				1880	
7/26/98 8:00	670	544.5	22	7						<2	<200				1810	47
7/26/98 20:00	682	556.5	21	8							<200				1670	
7/27/98 8:00	694	568.5	22	7							<200				1750	19
7/27/98 14:00	701	580.5	22	7	28	15	<2	<2	<2		<200				1800	
7/28/98 8:00	718	592.5	22	6						<2	<200				1700	20
7/28/98 20:00	730	604.5	20	7							<200				930	
7/29/98 8:00	742	616.5	20	7							<200				590	
7/29/98 20:00	754	628.5	20	6						<2	<200				976	
7/30/98 8:00	766	640.5	20	6							<200				1360	47
7/30/98 20:00	778	652.5	37	8						<2	<200				1400	
7/31/98 8:00	790	664.5	30	8							<200				1400	43
7/31/98 20:00	802	686.5									<200				1300	
8/1/98 8:00	814	698.5									<200				1500	47
8/1/98 20:00	826	710.5									<200				1500	
8/2/98 8:00	838	722.5									<200				1300	20
8/2/98 20:00	850	734.5								<2	<200				1900	
8/3/98 8:00	862	746.5									<200				1900	36
8/3/98 20:00	874	758.5	22	8							<200				2100	
8/4/98 8:00	886	770.5	21	6						<2	<200				2100	36
8/4/98 20:00	898	782.5	22	7							<200				2300	
8/5/98 8:00	910	794.5	21	6							<200				1500	19
8/5/98 20:00	922	806.5	21	7						<2	<200				2300	
8/6/98 8:00	934	818.5	22	5							<200				2100	18
8/6/98 16:00	946	830.5	22	7							<200				2000	

		Nitrate Results														
	(Hours)		NITRATE ANALYSIS RESULTS (PPM)													
	GAC	System	SAMPLE PORTS													
Date/Time	Run Time	Run Time	S1	S2	S2-01	S2-06	S2-10	S2-14	S2-18	S4	S6	S9	S11	S13	S15	S17
6/27/98 10:00																
6/28/98 10:00	2															
6/29/98 8:00	24															
6/30/98 9:30	49.5															
7/1/98 8:00	72															
7/2/98 8:00	96															
7/3/98 10:00	120	0														
7/3/98 22:30	132.5	7.5													<400	26
7/4/98 4:00	138	12.5		10	38	13		0.2	0.2	<2	<4				<400	52
7/4/98 8:00	142	16.5		11						<2	<100				2470	30
7/4/98 16:00	150	24.5		9	39	1.7	2	< 0.2	< 0.2	<2	<100				1120	41
7/5/98 0:00	158	32.5		13						<2	<10				<400	58
7/5/98 8:00	166	40.5	28	11						<2	<10				1240	44
7/5/98 16:00	174	48.5		13	39	22	2	<0.2	<0.2	<2	<4				<400	42
7/6/98 0:00	182	56.5		11						<2	<10				4900	51
7/6/98 8:00	190	64.5	28	11						1	0.2				<200	58
7/6/98 16:00	198	72.5		9						<2	<4				<400	33
7/7/98 0:00	206	80.5		12	38	18	2	<0.2	<0.2	<2	<4				<400	34
7/7/98 8:00	214	88.5		11						<2	<4	<200	<4	<200	<400	41
7/7/98 15:00	221	95.5		10						<2	<100	<200	<4	<200	1220	22
7/7/98 20:00	226	100.5		12												
7/8/98 8:00	238	112.5		10												
7/8/98 20:00	250	124.5		9												
7/9/98 20:00	274	148.5		14												
7/10/98 8:00	286	160.5		8												
7/10/98 20:00	298	172.5		11												
7/11/98 8:00	310	184.5		10	37	15	0.8	<0.2	<0.2							
7/11/98 20:00	322	196.5	24	9						<0.2						
7/12/98 8:00	334	208.5	23	9												
7/12/98 20:00	346	220.5		10												
7/13/98 8:00	358	232.5	24	11						<0.2						
7/13/98 20:00	370	244.5														
7/14/98 8:00	382	256.5														
7/14/98 20:00	394	268.5		11						<0.2						
7/15/98 8:00	406	280.5	23	11												
7/15/98 20:00	418	292.5		9												
7/16/98 8:00	430	304.5	23	11						<0.2						
7/16/98 20:00	442	316.5		10												
7/17/98 8:00	454	328.5	22	9												
7/17/98 20:00	466	340.5		10						<0.2						

	(Hours)		SULFATE ANALYSIS RESULTS (PPM)													
	GAC	System	SAMPLE PORTS													
Date/Time	Run Time	Run Time	S1	S2	S2-01	S2-06	S2-10	S2-14	S2-18	S4	S6	S9	S11	S13	S15	S17
7/18/98 8:00	478	352.5	58	<0.2												
7/18/98 20:00	490	364.5		0.2												
7/19/98 8:00	502	376.5	59	0.2						<0.2						
7/19/98 20:00	514	388.5		<0.2												
7/20/98 8:00	526	400.5	59	0.3												
7/20/98 20:00	538	412.5		0.6	0.7	0.7	0.7	<0.2	1.2							
7/21/98 8:00	550	424.5	59	0.4												
7/21/98 20:00	562	436.5		<0.2												
7/22/98 8:00	574	448.5	59	0.3						<2						
7/22/98 20:00	586	460.5		0.4						<2						
7/23/98 8:00	598	472.5	59	<0.2						<2						
7/23/98 20:00	610	484.5		<0.2						<2	90				9900	
7/24/98 8:00	622	496.5	60	0.3							80				8000	
7/24/98 20:00	634	508.5	63	<2							<200				8700	
7/25/98 8:00	646	520.5	59	<2						4	<200				7400	311
7/25/98 20:00	658	532.5	63	<2							<200				8600	
7/26/98 8:00	670	544.5	60	<2							<200				8200	371
7/26/98 20:00	682	556.5	59	<2						5	<200				9100	
7/27/98 8:00	694	568.5	60	<2							<200				8100	73
7/27/98 14:00	701	580.5	58	<2	<2	<2	<2	<2	<2		<200				7800	
7/28/98 8:00	718	592.5	58	<2						4	<200				8200	76
7/28/98 20:00	730	604.5	50	<2							<200				4400	
7/29/98 8:00	742	616.5	50	<2							<200				2500	290
7/29/98 20:00	754	628.5	49	1						1	170				4210	
7/30/98 8:00	766	640.5	48	1							220				5550	330
7/30/98 20:00	778	652.5	61	<2						3	<200				5400	
7/31/98 8:00	790	664.5	67	2							<200				4700	250
7/31/98 20:00	802	686.5									<200				5700	
8/1/98 8:00	814	698.5									<200				5300	317
8/1/98 20:00	826	710.5									<200				5600	
8/2/98 8:00	838	722.5									<200				5600	60
8/2/98 20:00	850	734.5								3	<200				7600	
8/3/98 8:00	862	746.5									<200				7700	160
8/3/98 20:00	874	758.5	44	<2							<200				6900	
8/4/98 8:00	886	770.5	43	<2						3	<200				6800	142
8/4/98 20:00	898	782.5	42	<2							<200				6300	
8/5/98 8:00	910	794.5	41	<2							<200				5200	39
8/5/98 20:00	922	806.5	41	<2						<2	<200				6600	
8/6/98 8:00	934	818.5	41	<2							<200				7200	39
8/6/98 16:00	946	830.5	41	<2							<200				7100	

		Sulfate Results														
	(Hours)		SULFATE ANALYSIS RESULTS (PPM)													
	GAC	System	SAMPLE PORTS													
Date/Time	Run Time	Run Time	S1	S2	S2-01	S2-06	S2-10	S2-14	S2-18	S4	S6	S9	S11	S13	S15	S17
6/27/98 10:00																
6/28/98 10:00	2															
6/29/98 8:00	24															
6/30/98 9:30	49.5															
7/1/98 8:00	72															
7/2/98 8:00	96															
7/3/98 10:00	120	0														
7/3/98 22:30	132.5	7.5								<2	<4				<400	59
7/4/98 4:00	138	12.5		0.2	0.5	0.5		0.7	0.7	<2	<4				<400	226
7/4/98 8:00	142	16.5		0.8						<2	160				1960	97
7/4/98 16:00	150	24.5		<0.2	1.3	<0.2	0.2	0.2	0.5	<2	180				1070	215
7/5/98 0:00	158	32.5		0.4						<2	<10				470	281
7/5/98 8:00	166	40.5	46	0.6						<2	<10				780	147
7/5/98 16:00	174	48.5		<0.2	0.3	<0.2	<0.2	<0.2	0.3	<2	<4				530	120
7/6/98 0:00	182	56.5		0.3						<2	14				4400	206
7/6/98 8:00	190	64.5	46	0.4						0.8	0.2				510	260
7/6/98 16:00	198	72.5		0.4						<2	<4				<400	77
7/7/98 0:00	206	80.5		0.8						<2	<4				<400	110
7/7/98 8:00	214	88.5		0.8						<2	<4	<200	<4	<200	20800	138
7/7/98 15:00	221	95.5		0.6						<2	160	350	<4	<200	600	39
7/7/98 20:00	226	100.5		0.5												
7/8/98 8:00	238	112.5		0.7												
7/8/98 20:00	250	124.5		<0.2												
7/9/98 20:00	274	148.5		2.4												
7/10/98 8:00	286	160.5		1												
7/10/98 20:00	298	172.5		0.3												
7/11/98 8:00	310	184.5	53	0.5	0.2	<0.2	0.3	<0.2	0.4							
7/11/98 20:00	322	196.5		0.4						0.3						
7/12/98 8:00	334	208.5	54	0.4												
7/12/98 20:00	346	220.5		0.5												
7/13/98 8:00	358	232.5	53	<0.2						<0.2						
7/13/98 20:00	370	244.5														
7/14/98 8:00	382	256.5														
7/14/98 20:00	394	268.5		0.3						<0.2						
7/15/98 8:00	406	280.5	54	<0.2												
7/15/98 20:00	418	292.5		0.4												
7/16/98 8:00	430	304.5	55	<0.2						0.5						
7/16/98 20:00	442	316.5		<0.2												
7/17/98 8:00	454	328.5	57	0.3												
7/17/98 20:00	466	340.5		0.2						<0.2						

	(Hours)		CHLORIDE ANALYSIS RESULTS (PPM)													
	GAC	System	SAMPLE PORTS													
Date/Time	Run Time	Run Time	S1	S2	S2-01	S2-06	S2-10	S2-14	S2-18	S4	S6	S9	S11	S13	S15	S17
7/18/98 8:00	478	352.5	30	39												
7/18/98 20:00	490	364.5		39												
7/19/98 8:00	502	376.5	30	39						40						
7/19/98 20:00	514	388.5		39												
7/20/98 8:00	526	400.5	30	40												
7/20/98 20:00	538	412.5		39	35	36	39	41	42							
7/21/98 8:00	550	424.5	29	39												
7/21/98 20:00	562	436.5		38												
7/22/98 8:00	574	448.5	29	38						160						
7/22/98 20:00	586	460.5		39						150						
7/23/98 8:00	598	472.5	30	39						170						
7/23/98 20:00	610	484.5								140	16600				21600	
7/24/98 8:00	622	496.5	27	37							16300				22300	
7/24/98 20:00	634	508.5	33	115							16000				27900	
7/25/98 8:00	646	520.5	34	119						150	17400				27800	108
7/25/98 20:00	658	532.5	33	102							15800				28300	
7/26/98 8:00	670	544.5	35	116							17100				28000	136
7/26/98 20:00	682	556.5	34	120						152	17900				27400	
7/27/98 8:00	694	568.5	35	117							16900				28500	50
7/27/98 14:00	701	580.5	32	107	67	80	107	144	162		15900				25600	
7/28/98 8:00	718	592.5	31	107						150	16600				25100	47
7/28/98 20:00	730	604.5	34	100							15900				27300	
7/29/98 8:00	742	616.5	33	100							16000				28200	93
7/29/98 20:00	754	628.5	32	98						148	16900				27900	
7/30/98 8:00	766	640.5	31	97							16200				27200	91
7/30/98 20:00	778	652.5	34	91						141	14000				23200	
7/31/98 8:00	790	664.5	34	89							14100				22600	73
7/31/98 20:00	802	686.5	31	87							13900				23100	
8/1/98 8:00	814	698.5	30	83							13700				23200	75
8/1/98 20:00	826	710.5									13900				22700	
8/2/98 8:00	838	722.5									14000				23000	34
8/2/98 20:00	850	734.5								142	16000				26900	
8/3/98 8:00	862	746.5									16600				26500	55
8/3/98 20:00	874	758.5									17500				28100	
8/4/98 8:00	886	770.5								137	18400				27900	48
8/4/98 20:00	898	782.5	29	85							17600				28100	
8/5/98 8:00	910	794.5	29	84							17500				28800	26
8/5/98 20:00	922	806.5	23	86						125	18300				27800	
8/6/98 8:00	934	818.5	23	90							17400				27800	26
8/6/98 16:00	946	830.5	28	78							17000				27600	

		Chloride Results														
	(Hours)		CHLORIDE ANALYSIS RESULTS (PPM)													
	GAC	System	SAMPLE PORTS													
Date/Time	Run Time	Run Time	S1	S2	S2-01	S2-06	S2-10	S2-14	S2-18	S4	S6	S9	S11	S13	S15	S17
6/27/98 10:00																
6/28/98 10:00	2															
6/29/98 8:00	24															
6/30/98 9:30	49.5															
7/1/98 8:00	72															
7/2/98 8:00	96															
7/3/98 10:00	120	0														
7/3/98 22:30	132.5	7.5		37	20	25		41	43	147	410				34900	30
7/4/98 4:00	138	12.5								121	490				31500	57
7/4/98 8:00	142	16.5		37						126	18100				30600	35
7/4/98 16:00	150	24.5		37	20	33	32	41	42	125	18400				31100	48
7/5/98 0:00	158	32.5		36						127	530				30300	72
7/5/98 8:00	168	40.5	18	37						127	1300				30500	49
7/5/98 16:00	174	48.5		36	19	22	34	41	43	158	200				32600	45
7/6/98 0:00	182	56.5		38						160	1640				25400	57
7/6/98 8:00	190	64.5	18	39						63	270				24000	61
7/6/98 16:00	198	72.5		42						136	440				32100	37
7/7/98 0:00	206	80.5		42	23	27	41	46	47	148	180				30900	42
7/7/98 8:00	214	88.5		42						149	180	4010	20	7230	11200	52
7/7/98 15:00	221	95.5		40						124	18000	3770	30	8780	30600	28
7/7/98 20:00	226	100.5		46												
7/8/98 8:00	238	112.5		43												
7/8/98 20:00	250	124.5		43												
7/9/98 20:00	274	148.5		45												
7/10/98 8:00	286	160.5		44												
7/10/98 20:00	298	172.5		33												
7/11/98 8:00	310	184.5	22	34	25	30	34	36	37							
7/11/98 20:00	322	196.5		35						37						
7/12/98 8:00	334	208.5	23	35												
7/12/98 20:00	346	220.5		35												
7/13/98 8:00	358	232.5	23	34						37						
7/13/98 20:00	370	244.5														
7/14/98 8:00	382	256.5														
7/14/98 20:00	394	268.5		35						37						
7/15/98 8:00	406	280.5	23	35												
7/15/98 20:00	418	292.5		35												
7/16/98 8:00	430	304.5	24	35						37						
7/16/98 20:00	442	316.5		35												
7/17/98 8:00	454	328.5	25	35												
7/17/98 20:00	466	340.5		37						40						

Appendix B

Memorandum

September 17, 1998

To: Main San Gabriel Basin Watermaster

From: McGuire Environmental Consultants, Inc.

Subject: Monitoring Results for Calgon Carbon's Perchlorate Removal Process

Introduction

Calgon Carbon Corporation (CCC) conducted pilot-scale testing using their Ion Separator (ISEP) system to study the removal of perchlorate from San Gabriel Basin groundwater. The testing was conducted at the Big Dalton Well in Baldwin Park between July 3 and August 7, 1998. Stetson Engineers Inc. did simultaneous parallel sampling twice a week. The purpose of this memorandum is to summarize the results of this parallel sampling.

Background

Perchlorate appears in inorganic chemicals as ammonium perchlorate (NH_4ClO_4), potassium perchlorate ($KClO_4$), sodium perchlorate ($NaClO_4$), and perchloric acid ($HClO_4$). These chemicals are used as oxidizers in rocket fuel, fireworks, munitions, and matches, in the refurbishing of solid rocket motors, in analytical chemistry, and in cattle feedlots as a food additive for cows. Its presence in drinking water supplies is typically a result of contamination from one of these sources, especially from the manufacturing of rocket fuels. The above mentioned salts are very soluble in water; therefore the molecule dissolves quickly producing the perchlorate ion (ClO_4^-) and ammonium ion.

Because perchlorate is not a regulated compound under the Federal Safe Drinking Water Act, only limited data are available for its occurrence and potential health risks. The primary health concern related to large dosages of perchlorate consumption is that it may slow the thyroid gland's absorption of iodine and hinder its production of a hormone named thyroxin, which controls human metabolism, growth, and development.

Perchlorate in San Gabriel Basin Groundwater

The California Department of Health Services (CDHS) first detected perchlorate in the San Gabriel Basin groundwater in the Baldwin Park area in June 1997. In February 1997, CDHS set a Provisional Action Level for perchlorate at 4 µg/L. In May 1997, CDHS revised its provisional action level from 4 µg/L to 18 µg/L because 4 µg/L could not be measured at that time.

Since the detection of perchlorate, the Watermaster has tested over 250 wells in the Main San Gabriel Basin to determine the dimension of the perchlorate contamination plume. Relatively high concentrations were found in a confined region, in a southwesterly direction from the Foothill Freeway (210) in Azusa to south of the San Bernardino Freeway (10) in Baldwin Park.

Ion Exchange Treatment Technology

The treatment technology used by CCC is a continuous, fixed-bed ion exchange adsorption. A strong base anion resin in the Cl form exchanges perchlorate. The resin used is highly selective for ClO_4^- ion. Perchlorate removal in the ion exchange resin can be described as follows:

$$\text{Resin-}Cl^- + ClO_4^- \Leftrightarrow \text{Resin-}ClO_4^- + Cl^-$$

The ISEP consists of 30 ion exchange columns that are mounted on a slowly rotating turntable. A simple schematic of the ISEP system is given in Figure 1. The ISEP system consists of 3 zones: adsorption, rinse, and regeneration. All of these zones are operated simultaneously as the turntable rotates continuously. The perchlorate is removed in the adsorption zone where water flows through 18 ion exchange columns in parallel. The next four columns operate in a countercurrent rinse mode and the last eight columns in a countercurrent regeneration mode.

The water used for rinsing the ion exchange resins is pre-softened. In addition, to producing as little wastewater as possible, the rinse water is used to dilute the highly concentrated regeneration solution. A sodium chloride solution is used to accomplish regeneration.

One total rotation of the ISEP takes 17 hours and the system reaches steady-state conditions after 3 rotations. The influent to the ISEP system was run through a granular activated carbon (GAC) filter first, as shown in Figure 1, because CCC had originally planed to use the existing GAC system at the well site before the ISEP. Not shown in Figure 1 is the reverse osmosis (RO) system within the ISEP system because it was only used the first few days of operation. The RO unit was meant to reduce the volume of wastewater, but CCC felt that it added unnecessary complexity to a pilot-plant scale operation.

Results and Discussion

Using the data from the parallel sampling, perchlorate removal is shown in Figure 2. During operation, it was observed that the perchlorate concentration in the well water dropped from around 50 µg/L to 18 µg/L. In the second stage of pilot operation the well water was spiked with perchlorate to a concentration of between 60 and 80 µg/L. In the first stage of operation, the perchlorate concentration of the ISEP effluent was non-detectable ($<$ 4 µg/L). In the second stage, when the well water was spiked with perchlorate, the perchlorate concentration of the ISEP effluent increased to around 10 µg/L but never exceeded the Provisional Action Level set by the CDHS. Overall, perchlorate removal was between 79% and 100% (average 94%). The increase to 10 µg/L was caused in part by CCC reducing the amount of brine used to regenerate the columns to determine the minimum amount of regenerant needed.

Nitrate removal is shown in Figure 3. The average nitrate concentration in the well water was around 18 mg/L as nitrate, and the average nitrate concentrations in the effluent were around 8 mg/L as nitrate. Nitrate removal was between 46% and 70 % (average 57%). The concentrations for nitrate in influent and effluent were very stable over the period of operation.

Finally, sulfate removal is shown in Figure 4. The influent concentration of sulfate varied between 40 and 80 mg/L. However, the effluent had a stable concentration of about 5 mg/L. The ISEP system removed between 84% and 100% (average 92%) of the influent sulfate concentration.

A summary of the observed ranges of concentrations of perchlorate, nitrate, and sulfate are given in Table 1. The complete listing of parallel results is attached to this memorandum.

Anion	**ISEP Influent**	**ISEP Effluent (Treated Water)**	**Brine**
Perchlorate, µg/L	18-81 *18-75*	< 4-14 *< 4*	0-8,000 *2,000-3,000*
Nitrate, mg/L as nitrate	17-21 *22-28*	5-10 *7-12*	20-4,000 *800-1,300*
Sulfate, mg/L	32-83 *45-60*	0-7 *< 0.5*	NA *2,000-3,500*

NA = Not Available

Table 1. Summary of observed ranges of concentrations gathered by parallel sampling performed by Stetson Engineers Inc. and CCC (presented at the Technical Committee Meeting in Azusa, August 7, 1998). CCC results are in Italics.

Conclusions

The data gathered by the parallel sampling conducted by Stetson Engineers Inc. confirmed the results presented by CCC at the Perchlorate Committee Meeting on August 7, 1998. CCC has shown that the ISEP is efficient in removing perchlorate from the Big Dalton Well water to non-detectable concentrations (< 4 µg/L). According to CCC it was possible to operate the ISEP with less than 1% of brine produced. The report prepared by CCC should be consulted for experimental details and information on costs of treatment.

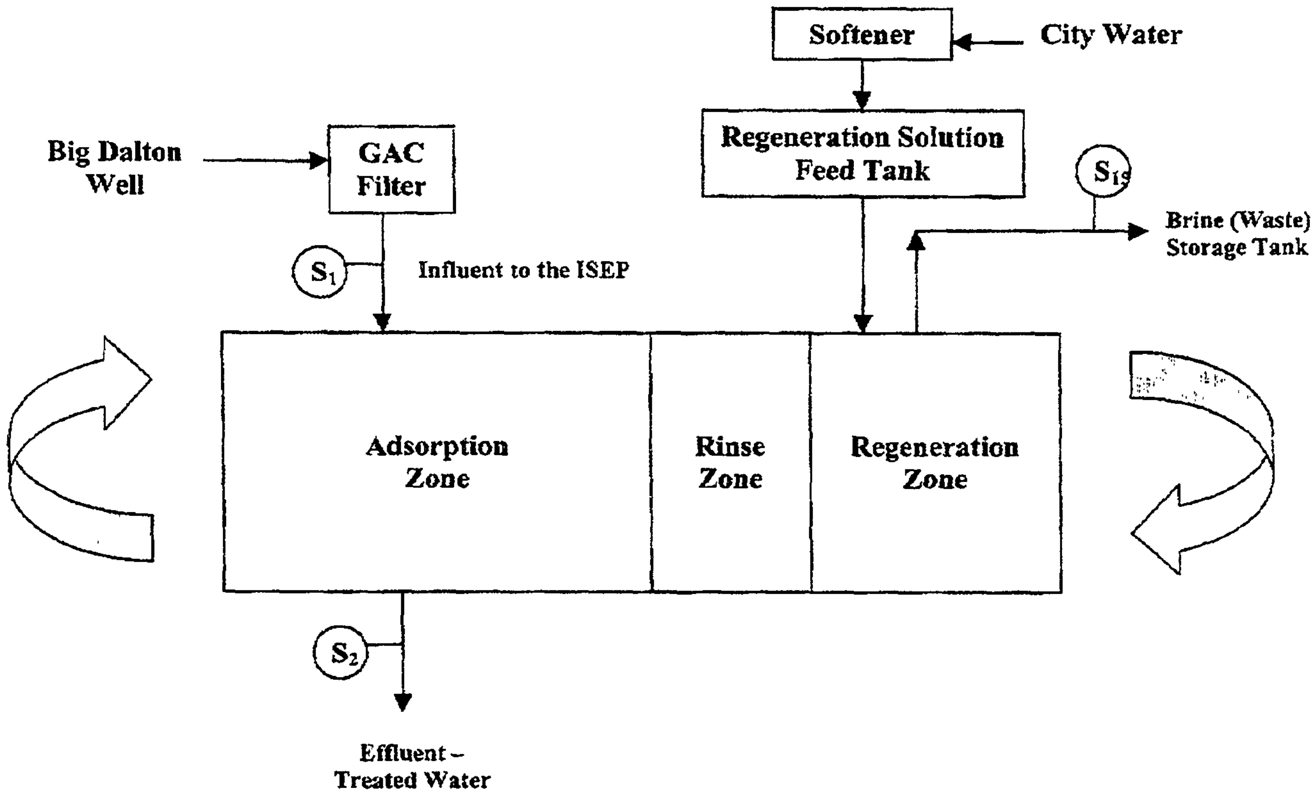


Figure 1: Schematic of the ISEP System from CCC

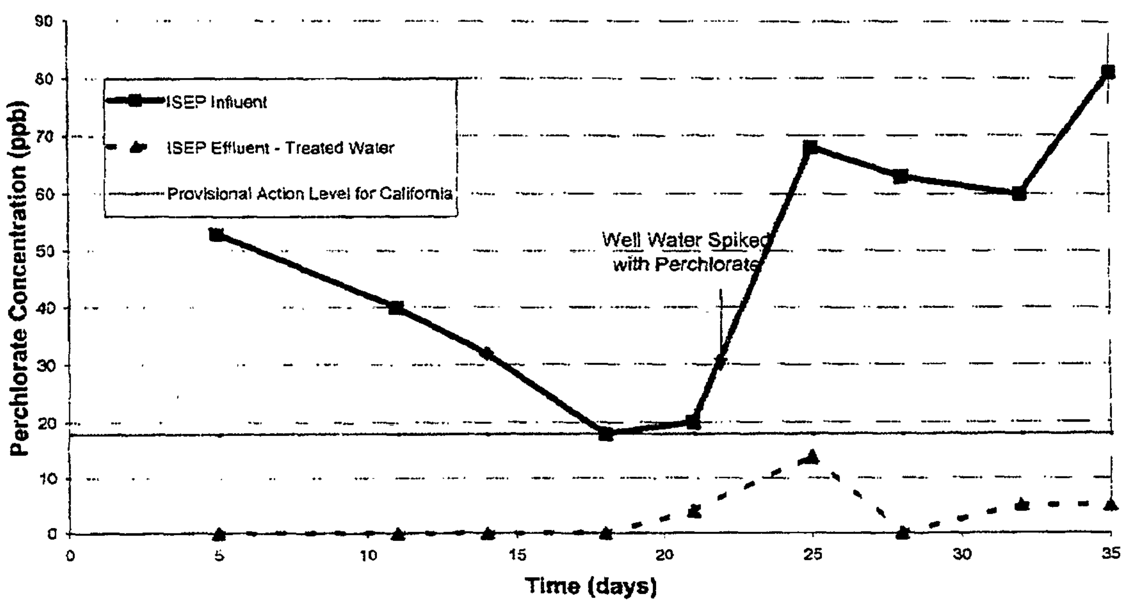


Figure 2: Perchlorate Removal from the Big Dalton Well

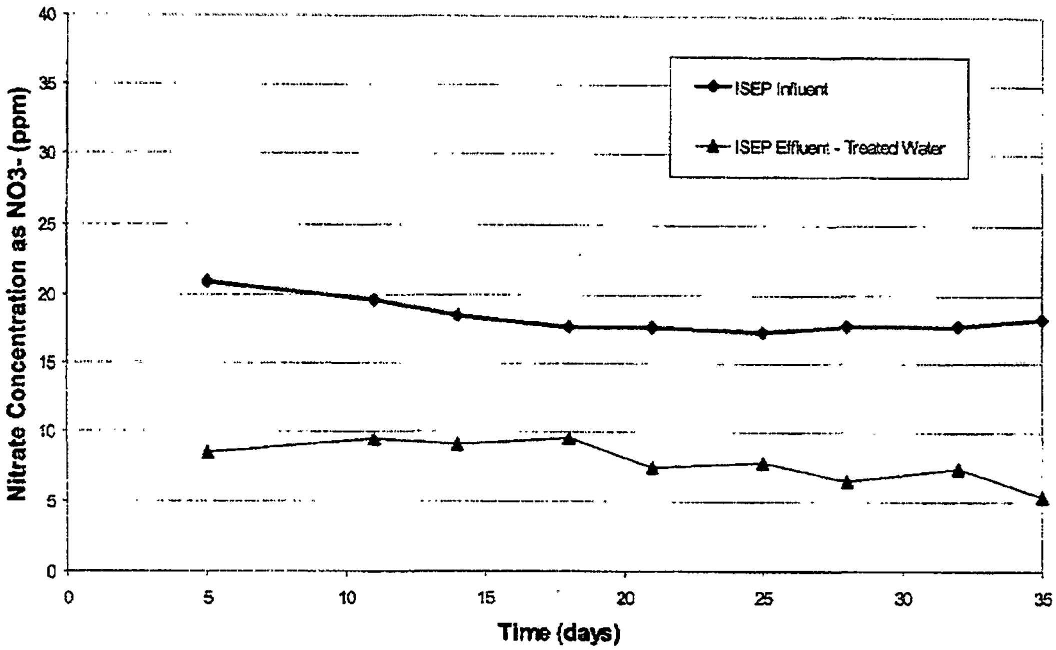


Figure 3: Nitrate Removal from the Big Dalton Well

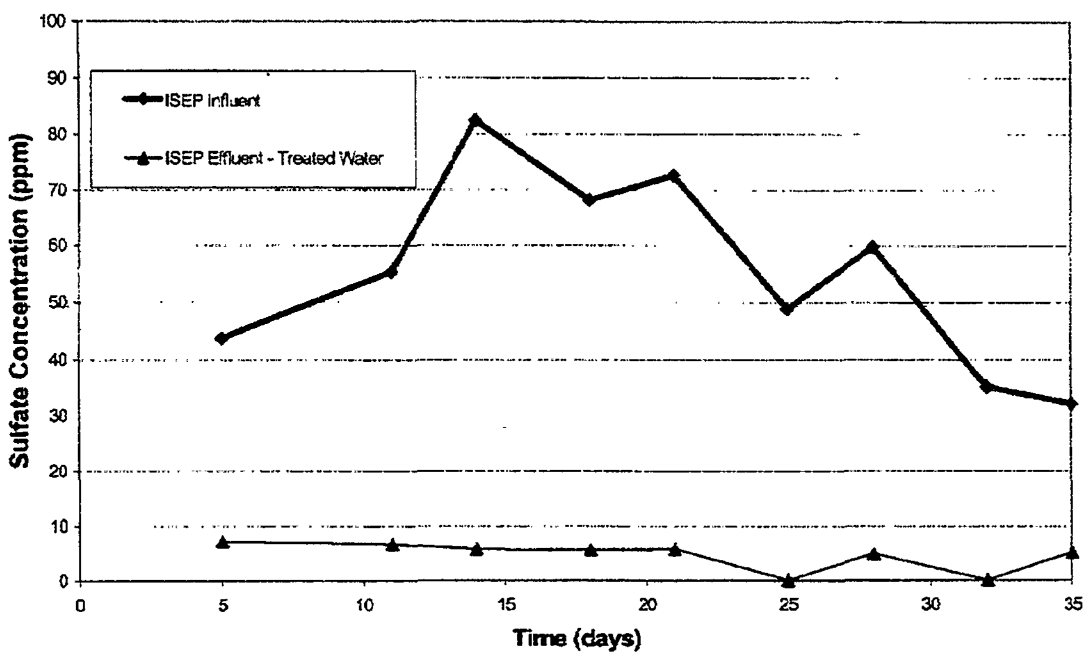


Figure 4: Sulfate Removal from Big Dalton Well

Summary of Parallel Sampling Results from Calgon Carbon Pilot Plant

Sampling Dates	Time (day)	S1 Perchlorate	S2 Perchlorate	S15 Perchlorate	S1 Nitrate	S2 Nitrate	S15 Nitrate
7-Jul	5	53	ND	ND	20.97	8.51	340.6
13-Jul	11	40	ND	3,900	19.58	9.51	3,988
16-Jul	14	32	ND	2,000	18.47	9.13	20.25
20-Jul	18	18	ND	1,100	17.61	9.58	1,181
23-Jul	21	20	4	1,600	17.63	7.45	1,662
27-Jul	25	68	14	7,400	17.24	7.88	1,734
30-Jul	28	63	ND	4,100	17.73	6.53	1,433
3-Aug	32	60	5	8,400	17.74	7.39	1,947
6-Aug	35	81	5	8,000	18.28	5.4	2,214
Averages		**48**	**7**	**4563**	**18.4**	**7.9**	**1613**

Sampling Dates	Time (day)	S1 Sulfate	S2 Sulfate	S1 TDS	S2 TDS
7-Jul	5	43.7	7.2	334	415
13-Jul	11	55.3	6.7	353	431
16-Jul	14	82.5	5.7	325	378
20-Jul	18	68.2	5.6	350	350
23-Jul	21	72.6	5.7	340	329
27-Jul	25	48 8	0	313	327
30-Jul	28	59.8	4.9	321	449
3-Aug	32	35.2	0	291	368
6-Aug	35	32.2	5.1	294	385
Averages		**55.4**	**4.5**	**325**	**381**

S1 = ISEP Influent
S2 = ISEP Effluent (Treated Water)
S15 = Brine

Sampling Dates	Time (day)	S1 Conductivity	S2 Conductivity	S15 Conductivity	S1 TOC	S2 TOC
7-Jul	5	501	550	74,150	ND	ND
13-Jul	11	493	538	82,700	ND	ND
16-Jul	14	500	539	77,600	0.3	0.2
20-Jul	18	610	664	98,800	0.4	0.5
23-Jul	21	458	526	68,800	0.3	0.5
27-Jul	25	516	556	75,800	0.3	0.3
30-Jul	28	471	485	78,155	1.1	0.3
3-Aug	32	449	496	74,500	0.5	0.3
6-Aug	35	641	468	105,710	0.8	0.8
Averages		**515**	**536**	**81802**	**0.5**	**0.4**

Comments:
Perchlorate in ug/L
Nitrate in mg/L
Sulfate in mg/L
TDS in mg/L
Conductivity in umho/cm
TOC in mg/L
Alkalinity in mg/L
Chloride in mg/L

ND = Not Detectable

Sampling Dates	Time (day)	S1 Alkalinity	S2 Alkalinity	S1 pH	S2 pH	S15 pH	S1 Chloride	S2 Chloride	S15 Chloride
7-Jul	5	156	126	7.473	7.145	8.904	31	92	4,274
13-Jul	11	140	112	7.491	7.215	8.69	42	100	3,439
16-Jul	14	132	109	7.065	6.923	9.012	46	101	3,434
20-Jul	18	116	101	7.155	7.075	8.832	54	113	3,264
23-Jul	21	120	93	7.34	7.202	9.047	50	111	2,539
27-Jul	25	118	95	7.975	7.32	9.039	52	113	27,936
30-Jul	28	119	86	7.33	6.916	8.872	45	100	2,449
3-Aug	32	122	93	7.237	6.944	8.81	40	98	5,398
6-Aug	35	125	82	7.079	6.511	8.727	36	95	4,629
Averages		**128**	**100**	**7.35**	**7.03**	**8.88**	**44**	**103**	**6374**